FUTURE OF ALUMINIUM INDUSTRY IN INDIA

a thesis submitted in partial fulfillment of the requirements for the award of degree of

Bachelor of Technology in Mining Engineering

by

Saswat Satchidananda

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National Institute of Technology Rourkela-769008

2012

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Under the guidance of

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2012

CERTIFICATE

This is to certify that the thesis entitled, "**Future of Aluminium Industry in India**" submitted by **Mr Saswat Satchidananda, Roll No. 108MN034** in partial fulfillment of the requirement for the award of Bachelor of Technology Degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

Date:

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A miscellany of such work could have never been possible without reference to and inspiration from the works of others whose details are mentioned in the reference section. I remain indebted to all of them.

At last, I thank all my friends who have patiently extended all sorts of aid and assistance for accomplishing this project work successfully.

Date: **Saswat Satchidananda**

CONTENTS

Abstract

The purpose of the project is studying the factors affecting the growth of Aluminium Industry and predicting the production of Aluminium for the next two decades.

Aluminium is the third abundant element in the earth crust. It never occurs as a free element. It is a silvery white metal with a wide range of application in the transport, construction, packaging industry, electronic production, household appliances, etc., and consequently the economic activities of these industrial sectors determine the overall demand for aluminium.

A model is designed to be a flexible tool in accommodating certain factors that impacts the metal's growth and its subsequent production in India. Consumption of Aluminium goes hand in hand with production. So a future prediction of Aluminium production is projected considering the Gross Domestic Product, Population, Power and Automobiles. The aluminium model simulates the technology evolution of the industry from 1980 to 2030, prior to primary Aluminium production. Several future projections has also been portrayed and correlated in the model to illustrate the technology dynamics of the sector's future.

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CHAPTER 1

INTRODUCTION

Background
Objectives
Methodology

1.1 Background

The aluminium industry is the largest non-ferrous metal industry in the world economy. Since its industrial production, demand for aluminium has been continuously increasing and its application has extended to variety of economic sectors. The production of the primary aluminium from bauxite is electricity intensive process and consumes majority of the energy used in the sector.

Aluminium production in India commenced in 1938 with the commissioning of Aluminium Corporation of India's (Indal) plant in collaboration with Alcan, Canada having a capacity of 2,500 ton per annum. It started with sheet production using imported aluminium ingots. In 1959, Hindustan Aluminium Corporation was set up at Renukoot, UP with an initial capacity of 20,000 ton per annum. Madras Aluminium Corporation, a public sector undertaking was commissioned then in 1965 with a capacity of 10,000 ton per annum followed by Balco in 1975, a PSU with a similar capacity of 10,000 ton. Finally in 1987, National Aluminium Company, a PSU with a capacity of 0.218mn ton was commissioned in collaboration with Pechinery of France.

In 1970s, the government brought aluminium industry under control through price distribution controls and barriers to entry. The 1970 Aluminium Control Order forced the Indian companies to sell 50 % of the aluminium produced for electrical purposes. Then the government decontrolled the industry in 1989 with the removal of the Aluminium Control Order with subsequent de-licensing the industry in 1991 and allowing the liberal import of capital goods and technologies. The aluminium demand grew at 6 % in the 80s. Aluminium demand post liberalization registered a growth rate of 12%. This coupled with the increase in the global aluminium prices ($1800/ ton in 1994) led to increased investments in this sector. The downstream capacity in the aluminium industry spurted due to sufficient duty differential between aluminium ingots or primary metal and value added downstream products. In March 1993 while the duty on aluminium ingots was 25% the duty on downstream products was 70%. However with the change in the tariff structure undertaken in the 1997 budget, duty on semi-fabricated metal was lowered to 25%. This change adversely affected the fortunes of the downstream producers.

Over the last few decades, global demand for aluminum is mushrooming, and it is now the second most widely used metal after Iron & Steel. (IAI 2008). Aluminum offers an attractive combination of high specific properties (e.g., strength-to weight), corrosion resistance, processability, and price – attributes which have promoted its widespread adoption. Today, it is not only most intensively used in the packaging and transportation sectors but also promoted to offer energy and environmental benefits, like for the light weighting of vehicles, reduction in the Greenhouse gases, etc. After oxygen and silicon, Aluminium is abundantly available in the earth's crust and deriving the metal from its bauxite ore requires large amounts of energy. Each kilogram of primary aluminum requires almost 200 megajoules (MJ) of energy to produce, about four times that of primary steel. (GREET 2006)

1.2 Goal and Specific Objectives:

The aim of the investigation is to project the demand of aluminium for next two decades. The aim was achieved by addressing the following specific objectives.

1. To find the relationship between Aluminium Production and factors such as Gross Domestic Product, Population, Power and Automobiles.
2. To predict the production of Aluminium for the next 20 years
3. To determine the GDP and population growth for the next two decades
4. To forecast automobile and electricity production for the next 20 years
5. To understand which of the above factors has a significant effect in determining the dynamics of the Aluminium industry.

1.3 Methodology:

The aim and objectives of the investigation were carried out by following a well-designed methodology (Figure 1). Statistical analyses were carried out. The model uses multiple regression analysis. It is a statistical technique that allows us to predict someone's score on one variable on the basis of their scores on several other variables. If two variables are correlated, then knowing the score on one variable will allow you to predict the score on the other variable. The stronger the correlation, the closer the scores will fall to the regression line and therefore the more accurate the prediction. Multiple regression is simply an extension of this principle, where we predict one variable on the basis of several other variables. Another model is also used for the validation of the reports and that is Auto-Regressive Integrated Moving Analysis (ARIMA)

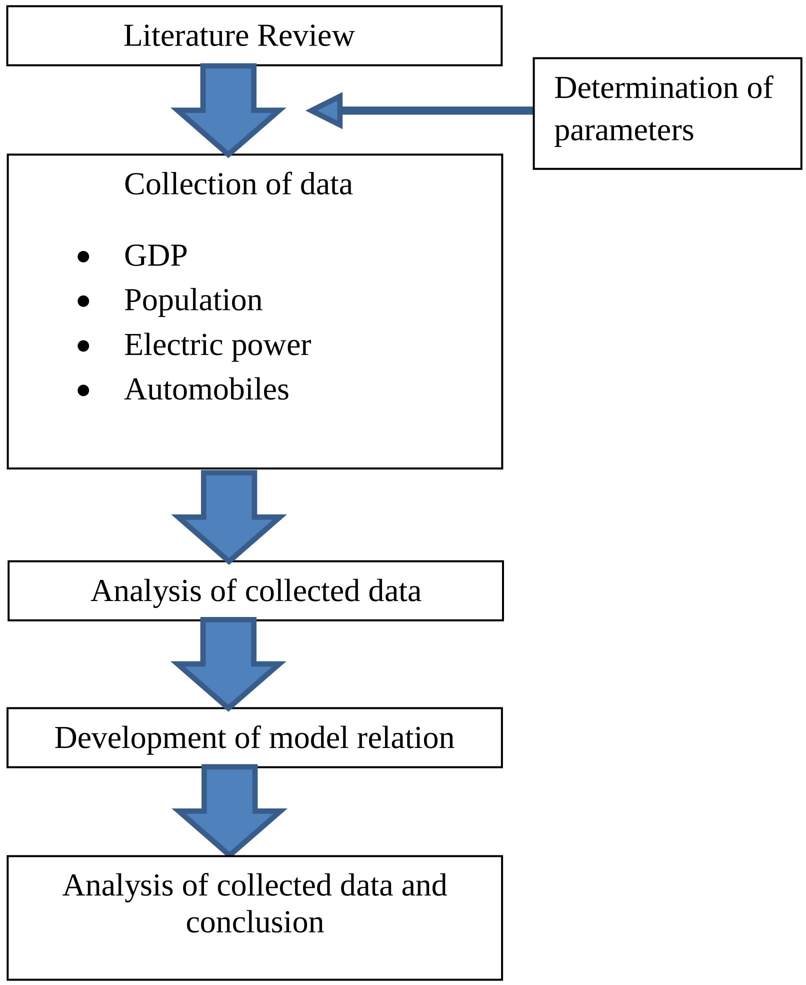


Figure 1: Flowchart of the model

CHAPTER 2

LITERATURE REVIEW

Global Aluminium Industry

Top Global Companies in Primary Aluminium

Indian Aluminium Industry

Transportation sector

Building and construction sector

Packaging sector

Engineering equipment, electronics and cables, and other sectors

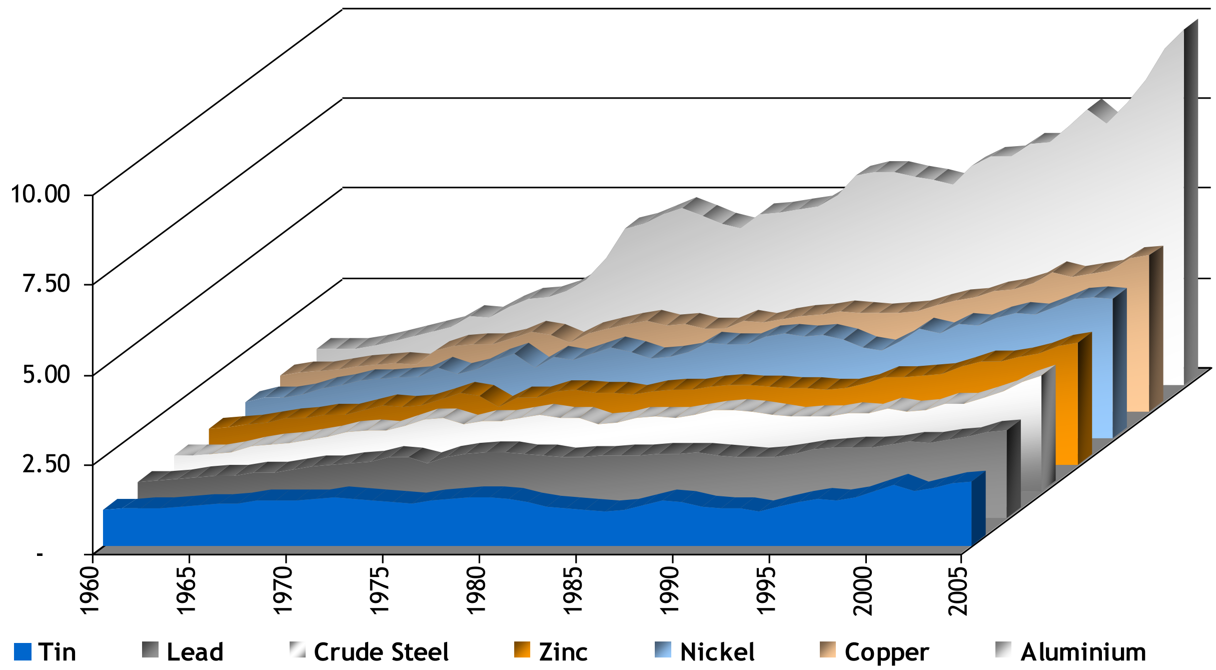
Benefits of Aluminium Products in Use

Industry process and technology

2.1 Global Aluminium Industry

Global Production

Global production of primary aluminium rose from 32 million tons (MT) in 2005 to 34 MT in 2006, a jump of 6%. Primary aluminium production is concentrated in relatively few countries. The top five producers—China, Russia, Canada, the United States, and Australia.



Source: Australian Commodity Statistics 2005, Barclays Capital

Figure 2: Comparison of Aluminium production to other metals

<u>Aluminium Producing Countries</u>

The ore of the metal i.e. bauxite generally occurs in the tropical and sub-tropical areas of earth. It is present in almost all continents except Antarctica with the estimated deposits of 65 billion tons. The major producers of primary aluminium in the world are:

· United States of America
· Russia
· Canada
· European Union
· Norway
· South Africa
· Venezuela
· Bahrain

· China

· Australia

· Brazil

· United Arab Emirates

· India

· New Zealand

The global production of aluminium figures around 38 million tons. The above-mentioned countries share more than 90% of the aluminium production. China and India reported the greatest increase in aluminium output i.e. at 12 percent and 11 percent respectively.

Global Consumption

Asia has shown the largest annual increase in consumption of primary aluminium, driven largely by the increased industrial consumption especially in China and India. Global consumption increased by 8.2% in 2006 and touched 34.7 MT. In 2007, the corresponding figures were 10% and 37.8 MT respectively. Globally, newer packaging applications and increased aluminium usage in automobiles and electronics is expected to keep the demand growth ever increasing for aluminium. Asia will continue to be the high consumption growth area led by China and India, which is expected to continue to register a double-digit growth rate for India in aluminium production in 2050.

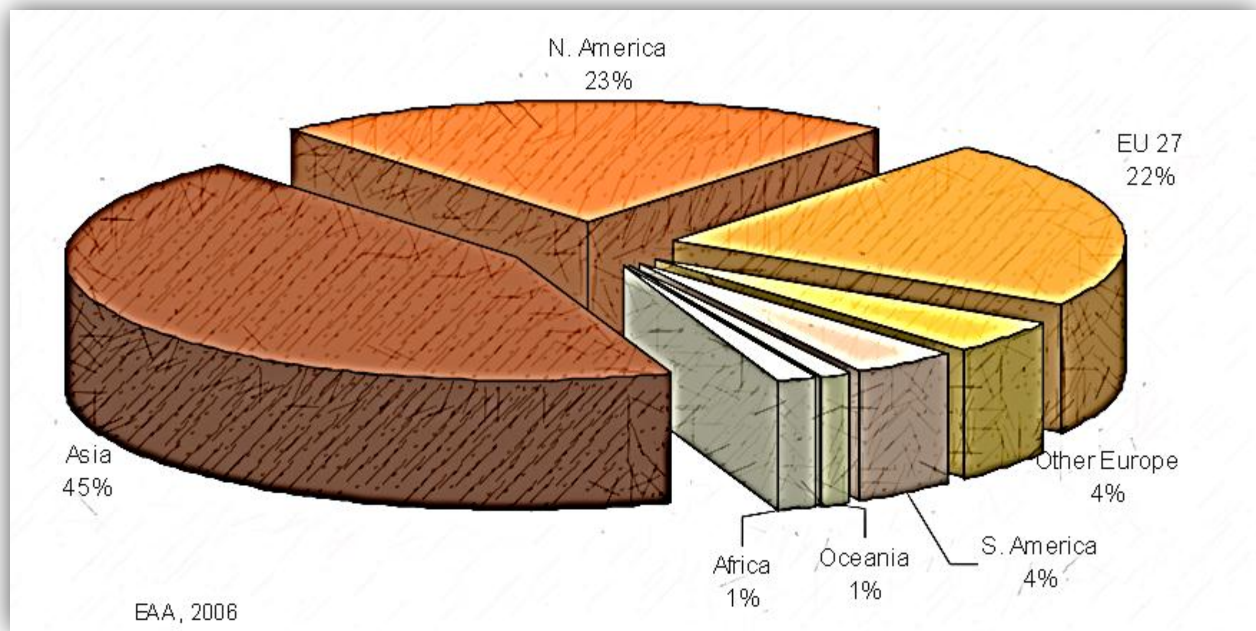


Figure 3: Primary aluminium: consumption share by regions

The following are the various applications areas of Aluminium.

1. Electrical
2. Construction
3. Packaging
4 Transportation
5. Engineering
6. Consumer Durables

2.2 Top Global Companies in Primary Aluminium

The top global companies in Primary Aluminium are

1. ALCOA
2. RUSAL
3. ALCAN
4. HYDRO
5. BHP Billiton
6. CHALCO
7. DUBALCO

2.3 Indian Aluminium Industry

The Indian aluminium sector is primarily run by large integrated players such as Hindalco and National Aluminium Company (Nalco). Other producers of primary aluminium include Indian Aluminium (Indal), now merged with Hindalco, Madras Aluminium (Malco)and Bharat Aluminium (Balco) the erstwhile PSUs, which have been acquired by Sterlite Industries. Consequently, mainly there are only three primary metal producers in the sector namely Balco (Vedanta), National Aluminium Company (Nalco) and Hindalco (Aditya Birla Group).

Characteristics and features of Indian Aluminium Industry

a) Highly concentrated industry with only five primary plants in the country.
b) Controlled by two private groups and one public sector unit (NALCO).
c) Electricity, coal and furnace oil are primary energy inputs.

d) Bayer-Hall-Heroult technology mainly used by all producers.

e) All plants have their own captive power units for cheaper and un-interrupted power supply.

f) Plants have set internal target of 1 – 2% reduction in specific energy consumption in the next 5 – 8 years

g) Energy cost is 40% of manufacturing cost for metal and 30% for rolled products.

h) Two plants have declared formal energy policy.

i) All the plants focus on Energy management.

j) Each plant has an Energy Management Cell.

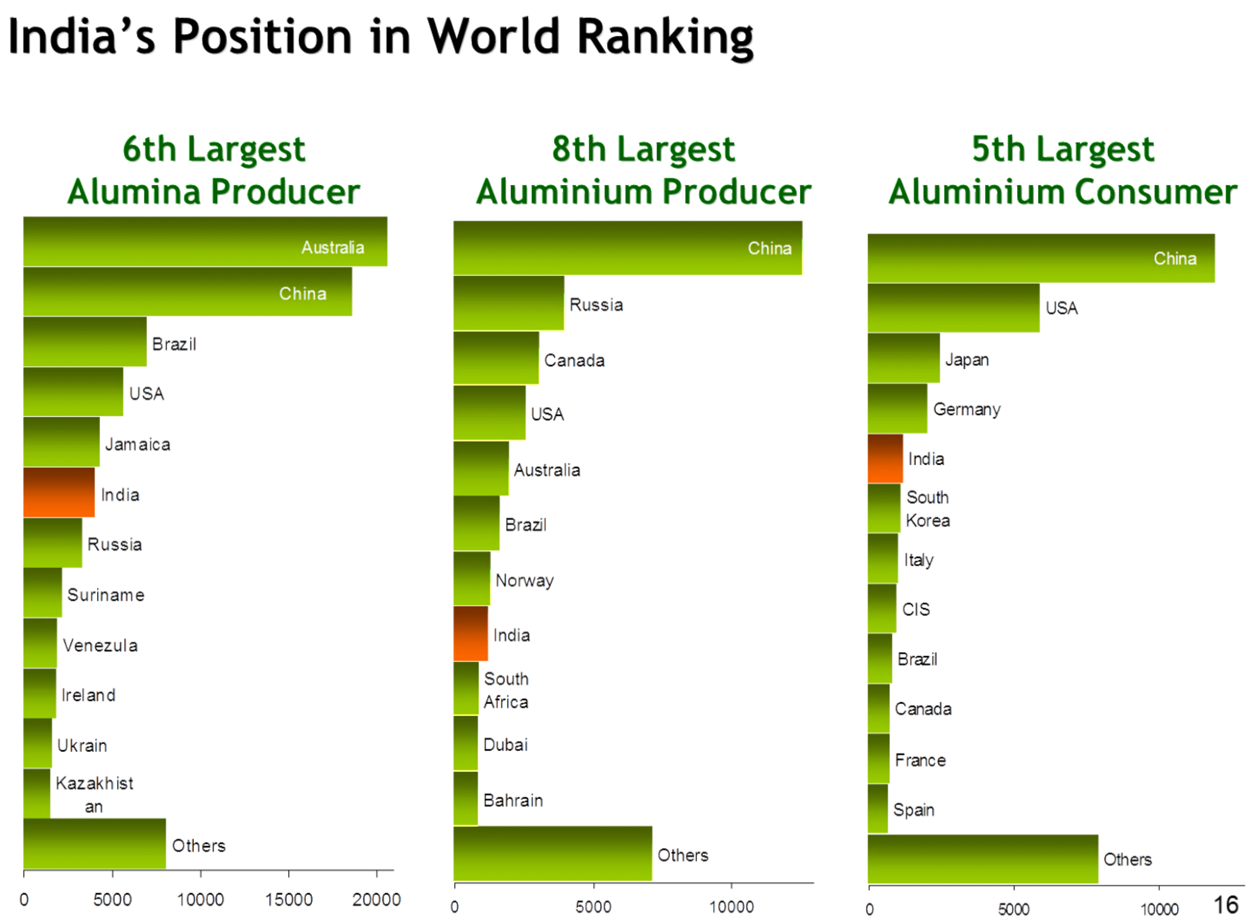


Figure 4: India's position in the world ranking

Primary Aluminium Production

India is considered to be the fifth largest producer of Aluminium in the world. It accounts to around 6% of the total deposits and produces about 2.1 million tons of aluminium in 2011. It is estimated that if the country's aluminium consumption rate maintains, it'd be having the reserves for over 350 years. India has confirmed 3 billion tonnes of Bauxite reserves out of the global reserve of 65 billion tonnes. Most of the bauxite mines are concentrated in Bihar, Karnataka and Orissa.

India is the eighth leading producer of primary aluminium in the world. The production of aluminium in India has grown substantially in the last five years. Production of Aluminium got a boost due to adding of extra smelting capacity in the recent years and rising domestic and user friendly demand emanating from packaging, construction, automobiles and electrical sectors and miscellaneous. Despite having 7.5 per cent of the world's total bauxite deposits and 7 per cent of bauxite production, India's contribution in global aluminium production is less than 5 per cent.

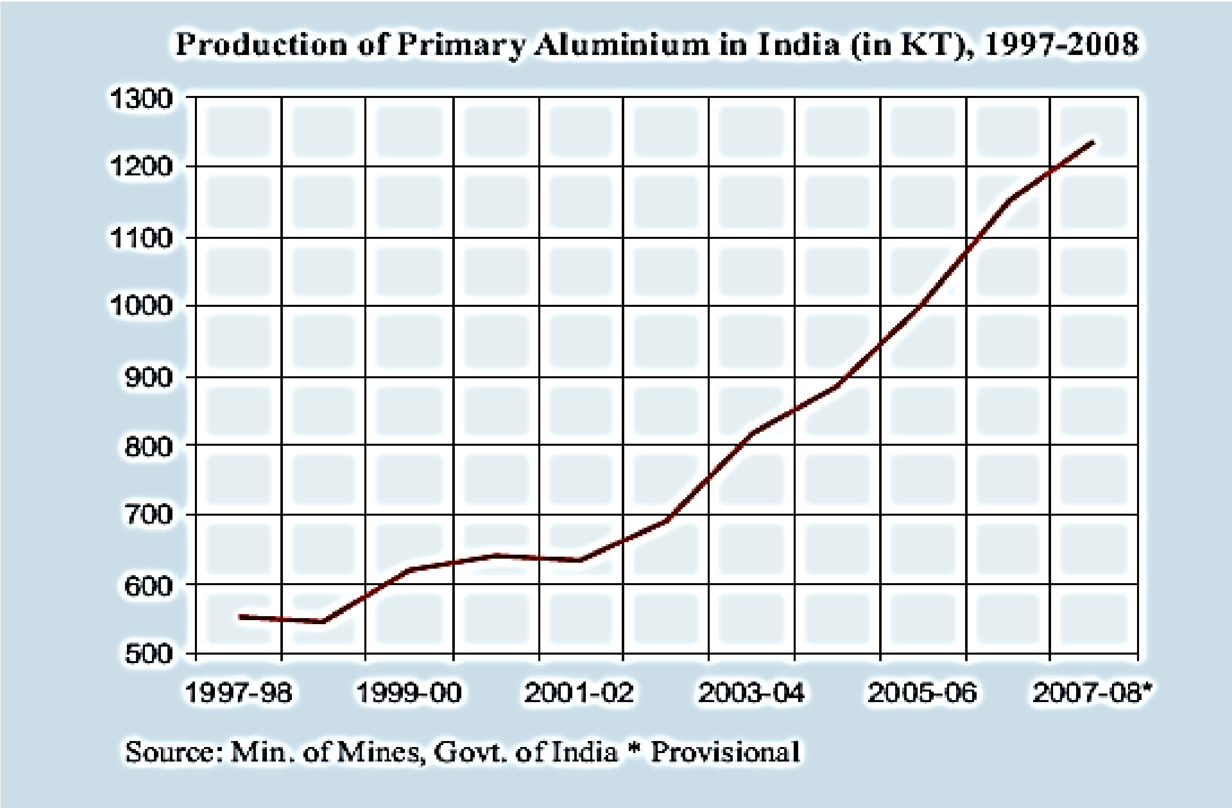
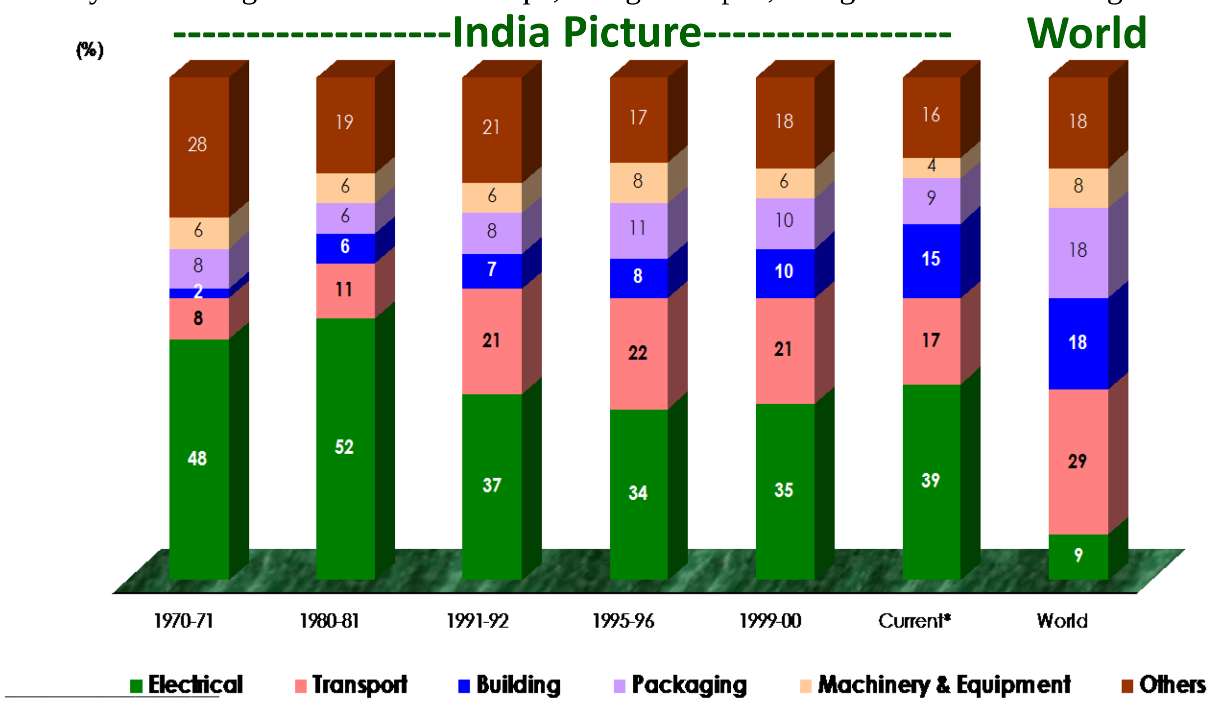


Figure 5: Production of primary aluminium in India

Consumption

The consumption of primary aluminium has risen sharply since 2005 and reached 2,100 KT by 2011. From the end of the 1980s till 2002, the consumption remained almost stagnant, around 500- 600 KT. The main reason for this mushrooming growth after 2002 lies in the demand generated from the automobile sector, construction, electrical and packaging sectors. The per capita consumption of aluminium continues to remain very low at around 1.3 kg as against nearly 25 to 30 kgs in the US and Europe, 15 kgs in Japan, 10 kgs in Taiwan and 3 kgs in China.



Source: World - Barclays & Alcoa
India – Company Data

Figure 6: Change in consumption pattern over years

The key consumer industries in India are transportation, consumer durables, power, electrical sector, packaging and construction. From the figure we can infer power is the biggest consumer (about 44% of total) followed by infrastructure (17%) and transportation (about 10% to 12%). However, internationally, the pattern of consumption is in favour of transportation, primarily due to large-scale aluminium consumption by the aviation space and shipping.

2.4 Transportation sector

The transportation sector is one of the main consumers of aluminium, although, depending on the industrial structure of a region/country, this situation may vary significantly. Aluminium is used as a component in cars, commercial vehicles, aeroplanes, trains, ships, spaceships etc.

The Automotive industry in India is one of the largest industries in the world and it has been growing tremendously. Passenger cars and commercial vehicles manufacturing industry of India is the seventh largest globally, with a production of more than 3.7 million units annually in 2010. Reports have documented that India is set to overtake Brazil to become the sixth largest passenger vehicle producer in the world, growing at a rate of 16-18 per cent to sell around three million units in the course of 2011-12. In 2009 according to statistics, India emerged as Asia's fourth largest exporter of passenger cars, behind Japan, South Korea, and Thailand.

The Automobile Industry in India is manufacturing over 11 million vehicles and exporting about 1.5 million annually. The main products of the industry are the two wheelers (with a market share of over 75%) and passenger cars (with a market share of about 16%). Unbelievable but true that 91% of the vehicles sold are used by households and only about 9% are used for commercial purposes. Commercial vehicles alongwith three wheelers share about 9% of the market between them. The industry has incredibly attained a turnover of more than 35billion$ and provides employment to over 130 lakh people.

2.5 Building and construction sector

In countries without an automobile industry, the building and construction sector shares the largest markets of aluminium. However, it may vary considerably from country to country and over regions due to the level and type of sector activities, which implies that the scrap generation will also be different. The total stored aluminium metal in the sector is the amounting to nearly 170 Mt worldwide. However, as already mentioned, due to the very long lifetimes of buildings, their contribution to recycled scrap was only 7% in 2004, i.e. around 0,5 Mt in total.

The main use of aluminium in this sector is

1. To provide materials for roofing and cladding and
2. Window and door frames, as well as small applications such as door handles, shutters, ceiling partitions, etc.

A study on the collection of aluminium scrap from building deconstruction and demolition is high though the aluminium content in buildings is below 1%. Collection of the small items depends largely on the demolition method, the large items are often collected separately in order to be directly sold for reuse or sent for recycling. Insufficient data on annual deconstruction and demolition means that an estimation of the rate of aluminium scrap collection in this sector is impossible. Taking sector's consumption into account, the yearly recycling rate of the sector is near 5%, and it is rising due to the incremental use of aluminium in the past.

2.6 Packaging sector

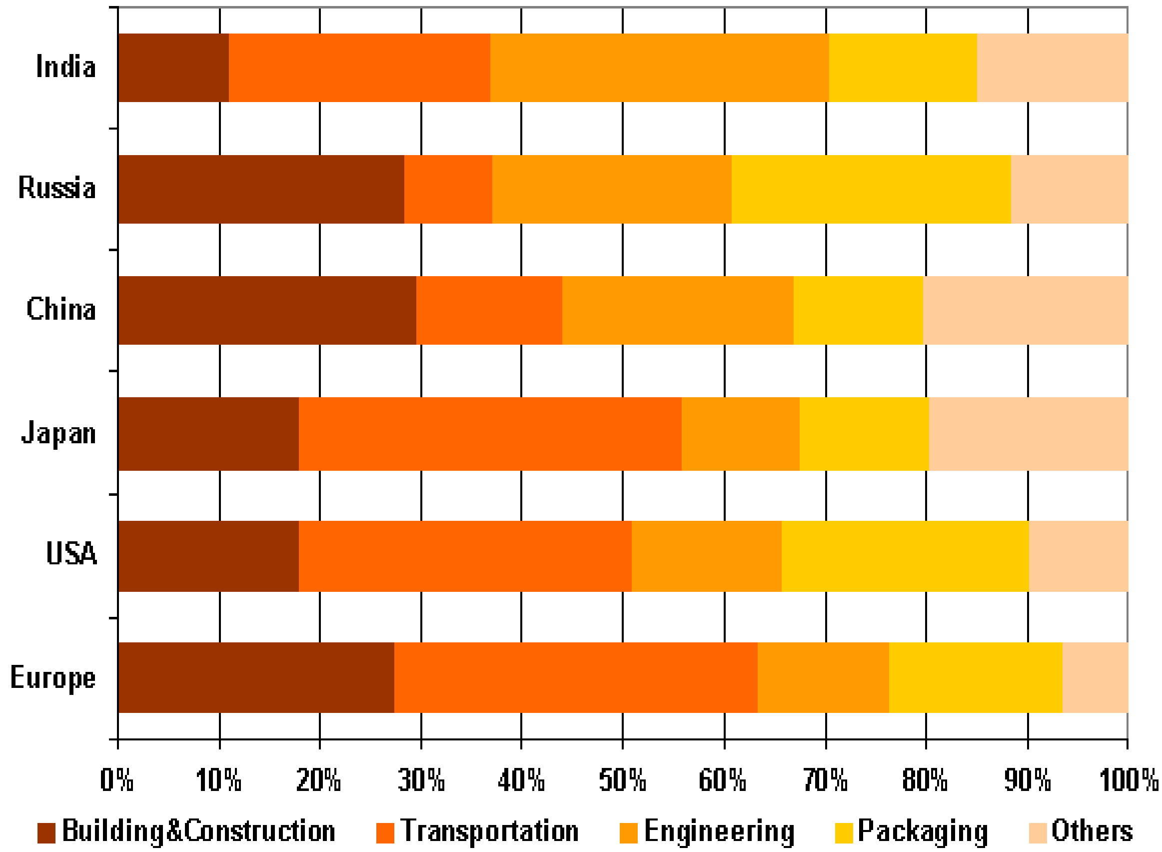
Most of the products in food packaging have less than a year life time. The current consumption at world level is near five Mt per year. Aluminium packaging waste is a large short term source of scrap. This sector contributes to nearly 28% of the recycled aluminium globally, second after the transportation sector. The overall rate of recycling of aluminium in the sector is around 36%, mainly from beverage cans and foodstuff covers. In the package industry two different types of aluminium products are usually distinguished in this sector, i.e. rigid and semi-rigid, and flexible packaging, with the first one having high aluminium content and the latter low in aluminium content. Mostly the used beverage cans (UBCs) are the recycled aluminium products of the sector, while the others are rarely recovered. Per capita, the world's average use of aluminium cans is around 26 units; however, it ranges from six in Germany and Asia to 334 in USA alone.

The difference is due to the fact that the alternatives in some countries, steel and paper cans/cartons, are more popularly used. The UBC recycling technology has been well established and the rate of collection has reached 60% as the world average and 46% in Europe in 2002. Japan, Brazil and Norway have reported a collection rate of more than 90%. Now USA, being the single largest consumer, potentially generates more than half of the scrap of this sector, though its collection rate is just over 50%.

2.7 Engineering equipment, electronics and cables, and other sectors

Aluminium is also widely used in electrical applications, machinery and equipment especially on the Indian grounds. Globally these sectors, here called as the engineering, electronics and cable sector, represents around 18% of the market and is responsible for 10% of the recycled aluminium. The life time of electrical products and equipments in this sector varies from a few years to some 50 years, making the estimation of scrap supply difficult. Referring recent data as an indication, the average recycling rate of the sector is 10-12%.

Similarly, the rest of the applications, here referred to as the other sectors, takes 16% of the market share and provides another 10% of recycled aluminium globally



Source: EAA, 2006

Figure 7: The sector wise global consumption pattern of Aluminium

We observe from the above figure that 29% of all Aluminium is consumed by the transportation sector. This is because of the boom in the aviation, shipping and automobile industry. As Aluminium is a complementary to steel and can be harnessed for better, the consumption for aluminium has substantially increased.

Aluminium is the second most consumed metal on the earth after iron, and is consumed and produced more than all non-ferrous metals combined together. By 2030 I bet to state that the primary aluminium consumption will cross more than 70,000 kilo tonnes (KT). At the beginning of this century, consumption was 25,059 KT and since then it has grown steadily mainly on demand from Asia, in particular China. The total global consumption of aluminium stood at 33,970 KT in 2006 and has reached 37,800 KT in 2008. The overall demand saw a drop only in the 2001 when consumption was at 23,722 KT.

<u>Now the Question arises:</u>

Why Aluminium?

Aluminium usage in the modern era has not only increased the efficiency but also has solved the problem of reducing energy consumption and greenhouse gas emissions. Some of the major benefits of this unique metal are ascribed below:

Strength

Aluminium when mixed with small amounts of other metal to form alloys (ex. Germanium), it can provide similar strength of steel, with only one-third of the weight.

Durability

Aluminium forms a thin insulating sheet when sprayed on a polymer.

Impermeability

Aluminium serves an excellent barrier function. It is ideal for food and drink packaging and containers. It keeps air tight, is light and keeps out microorganisms.

Flexibility

Aluminium and its alloys can be easily shaped by any of the main industrial metalworking processes by combining properties which also ensures rolling, extrusion, forging and casting

Corrosion-resistant and coating

Aluminium oxide (natural coating) provides a highly effective barrier to the ravages of air, moisture, temperature and chemical attack which makes Al a useful construction material.

Light weighted

Aluminium used in transport sectors reduces the weight of the vehicles, hence provides fuel efficiency reducing energy consumption and greenhouse gas emissions.

Recycling

Aluminium can be recovered by recycling it again and again, using only a very small fraction of the energy required making "new" metal. It is found that recycling saves around 95% of the energy required for primary production of Aluminium.

Other

Aluminium, a superb conductor of electricity has seen replacing copper in many electrical applications. Moreover it is non-magnetic and non-combustible, properties highly essential in advanced industries such as electronics or in offshore structures.

2.8 Benefits of Aluminium Products in Use

Transport

i. 15 million tonnes of aluminium used in transport applications – cars, buses, trucks, trains and ships – can save up to 300 million tonnes of CO2 and 100 billion litres of crude oil over the vehicles' operating life.

ii. The use of one kg of aluminium replacing heavier materials in a car or light truck can save a net of 20 kg of CO2 over the life of the vehicle.

iii. This figure is even higher for more weight sensitive applications (for instance, up to 80 kg CO_2 saved per kg of aluminium used in trains and ships).

iv. In 90s, the average passenger car contained between 40 and 80 kg aluminium; but today, the average is between 120 and 150 kg.

v. While today aluminium accounts for less than 10% of a car's total weight it represents up to 50% of the total material scrap value.

vi. As car manufacturers have sought to improve fuel efficiency, the use of aluminium has grown every year for the past 30 years.

vii. The aluminium industry supports global university research in recycling, vehicle light weighting and improvements in alloy properties.

Building & Construction

i. Aluminium is durable and corrosion resistant, hence reducing maintenance over time.

ii. Aluminium's unmatched recyclability is user friendly and gives architects a key sustainability design tool.

iii. Most energy efficient buildings start with aluminium. Aluminium components and designs optimize natural lighting and shade and enhance energy management and support designs that make the most of the physical environment.

iv. Globally, buildings contain some 200 million tonnes of aluminium, which will be available for recycling by future generations time after time - an energy bank for future generations.

v. The metal's inherent strength allows aluminium window and curtain wall frames to be very narrow, maximizing solar gains for given outer dimensions.

vi. Aluminium's high strength-to-weight ratio makes it possible to design light structures with exceptional stability.

Packaging

i. Aluminium packaging (its unique combination of properties) contributes to the efficient fabrication, distribution, storage, retailing and other end usage of products.

ii. The aluminium beverage can is one of the most sustainable packaging solutions available, because it not only protects its contents but is cost-effective and can be recycled after use.

iii. Aluminium foil serves as a lightest 'complete barrier' material in a packaging composite.

iv. According to sources 30% of the food in developing countries perishes due to the lack of packaging. But aluminium has the best barrier options to keep food and drinks fresh and safe and to avoid loss. Moreover it guarantees a longer shelf-life, contributing to the sustainability of food and drinks products.

v. Aluminium due to its inertness helps to reduce the impact of used packaging. It is light and minimizes packaging volumes within cheaper limits.

vi. Special packaging by maintaining sterile conditions of pharmaceuticals and other medical sensitive products protects during transportation and storage until use. The high economic value of used aluminium packaging serves as an incentive for continuous improvement in recycling process.

vii. Studies have documented that the aluminium cans are the most recycled beverage container in the world and most aluminium foil applications are fully recyclable.

2.9 INDUSTRY PROCESS AND TECHNOLOGY

(source-Luo Zheng and Soria Antonio, "Prospective Study of the World Aluminium Industry" European Commission, Joint Research Centre, Institute for Prospective Technological Studies 2008)

The aluminium industry consists of four subsectors:

- Bauxite mining
- Alumina refinery
- Primary aluminium smelting
- scrap recycling and secondary aluminium refinery each having their own distinguished characteristics, production processes, technologies, resources and energy demand:

Bauxite mining

Bauxite mainly consists of aluminium hydrates. The bulk of its known reserves are located in countries of the southern hemisphere, e.g. Guinea, Australia, Jamaica, etc. Nearly all bauxite is mined by open-pit mining because underground mining tends to be more costly. Generally bauxite is extracted from a site by removing the overburden and blasting the bauxite deposit with explosives and loosening them, depending on its hardness and other local conditions.. The mining site residues and wastes are then treated and the site is restored. However Bauxite mining and trade are not included in the present model.

Alumina refining

There are four different processes identified in the current alumina production, the Bayer process, and three alternative processes, i.e. the Sinter process, the combined/parallel Bayer-Sinter process and the Nepheline-based process. The Bayer process is the most widely used form of alumina extraction. The method was developed in the late 1800s and has been the conventional and most efficient process for alumina hydroxide manufacturing.

The *Bayer process* can be summarised as the following:

a) The bauxite is ground and combined with hot caustic liquor either in ball or rod mills, to form slurry. Caustic soda is added to the slurry and the mass is then steam heated in digesters. The solution is approximately 30% NaOH at a temperature between 150 and 230^oC

b) The resulting liquor contains a solution of sodium aluminate and undissolved bauxite residues which contain iron, silicon and titanium. The slurry is flash cooled and an insoluble residue, known as red mud, is separated from the aluminate liquor. The green liquor is then passed through sand bed filters to be clarified.
c) The sodium aluminate solution is then pumped to the precipitation stage. The aluminate is further cooled to between 60-75^oC, and fine particles of alumina are added to seed the precipitation pf pure alumina particles as the liquor cools. Seed hydrate crystals are added to the solution to promote the growth of alumina hydrate crystals. The precipitate sinks to the bottom of the tank, is settled and filtered off.
d) Finally, the washed crystals are dried and calcinated in fluid bed or rotary kiln calciners at a temperature of around 1000^oC.

In total the alternative processes produce 17% of the world's alumina, and majority of them are located in China and Russia. The alternative processes mainly aim at accommodating different raw materials and improving the recovery rate of alumina. Due to the variety of aluminous materials used in alumina production, the **Bayer-Sinter process** is favoured in China. However, high energy consumption has been the drawback of the Sinter process, which requires 30-40 GJ/tonnes alumina in comparison to 11GJ/tonne for the Bayer process. The Sinter process typically results in the production of large amounts of leached residue which can be used for cement production, and combined alumina and cement production could reduce the cost of mud disposal significantly as is the case in China.

Because of the lower alumina content of nepheline ore (a silica-undersaturated aluminosilicate, $Na_3KAl_4Si_4O_{16}$), the **Nepheline-based process** requires the handling of a greater volume of material (4.8 tonnes to one tonne of alumina) and results in various by-products of substantial amounts. Consequently, this process has a much higher cost than the Bayer process and only becomes economically viable when all the by-products can be sold. Currently, production of alumina from nepheline ore exists only in Russia and Iran, totaling 1.3 Mt of alumina in 2002.

Primary aluminium production

Primary aluminium is produced entirely through the Hall-Héroult process, which involves the electrolysis of alumina dissolved in a bath of molten cryolite (Na_3AlF_6) at a temperature of 960 ^oC. The electrolytic cells comprise a carbon cathode, insulated by refractory bricks inside a rectangular steel shell, and a carbon anode suspended from an electrically conductive anode beam. The cells are connected in series to form an electrical reduction line. A direct current is passed from a carbon anode through a bath to the cathode and thence, by a busbar to the next cell.

Alumina content in the molten bath is maintained at 2-6% and computer controlled addition is common in a modern plant. When alumina content in the electrolyte bath falls too low, the bath itself would start the electrolytic reaction with the carbon in the anode, the so-called anode effect, producing two types of PFC gases, i.e. CF4 and C2F6. Furthermore, fluoride compounds, mostly as aluminium fluoride (AlF3), are added enabling the cells to be operated at a lower temperature. Currently, most cells are now operated with the AlF3 content of the bath significantly in excess of the stoichiometric cryolite composition, consequently with potentially increased fluoride emissions.

Liquid aluminium is deposited at the cathode in the bottom of the cell and oxygen combines with carbon anode, to form carbon dioxide. The carbon anodes are therefore continuously consumed during the process. The molten aluminium is periodically withdrawn from the cells by vacuum siphon into crucibles. The crucibles are transported to the casting plant and the aluminium is emptied into heated holding furnaces. Alloying additions are made in these furnaces with controlled temperature.

Secondary aluminium production

Secondary aluminium is produced from recycled scrap that is either generated at the smelter and fabrication plants or collected post consumption. Thus the aluminium scrap is categorized as:
new and old, due the distinction of pre or post consumption.

Sources of new scrap are the production plant of primary aluminium and plants that use aluminium as the input material. Usually there is no need for sorting of the new scrap and it can be used on-site at the smelter or transported directly to a secondary refiner or remelter.

Pretreatment is only needed when the new scrap includes alloys. Old scrap is waste material that has high aluminium content, such as electronic appliances, automobile parts, construction material, packaging material, etc. Secondary producers are usually distinguished as refiners and remelters. Refiners produce casting alloys and deoxidation aluminium from scrap of varying composition, and are able to add alloying elements and remove certain unwanted elements after the melting process. Remelters produce wrought alloys from mainly clean and sorted wrought alloy scrap. The secondary aluminium production process from old scrap includes: old scrap collection and sorting, scrap pre-treatment, and melting and refining. The main feature of the production rocess is the diversity of raw materials encountered and the variety of furnaces used. The type of raw material and its pre-treatment is therefore used to judge the best type of furnace to be used for a particular type of scrap with its size, oxide content and degree of contamination among others. Therefore, the choice of process technology, in most cases, varies from plant to plant, and there are potentially many possible strategies to set up the process for the treatment of similar input material.

CHAPTER 3

DATA COLLECTION

Factors Impacting Aluminium production

Data Collection

3.1 Factors Impacting Aluminium production

Consumption of aluminium in India has been increasing since 80s and at a 4% growth rate annually since 2000. As a commodity and one of the important input materials to a variety of industries, aluminium consumption responds to economic activity. Therefore, the demand for aluminium and the commodity intensity (commodity consumption per unit of GDP per capita) can be assumed to correlate to GDP and Population. Aluminium consumption in each region is considered to be closely related to the GDP and Population.

The evolution of primary aluminium production technology is driven by electricity efficiency, which will not only affect production costs and energy consumption, but also reduce both process and energy related emissions.

Moreover recent rise in the transportation sector, be it in the aviation, automobiles, naval or space, has led to the increased use of Aluminium and its alloys. The Indian Automotive Industry embarked on a new journey in 1991 with delicensing of the sector and opening the gates for FDI through automatic route. Since then almost all the global major players have set up their facilities in India taking the level of production of vehicle from 2 million in 1997 to 20 million in the next 15 years then. Based on all four major factors affecting the aluminium production, the following datas has been collected from various sources whose references are mentioned in the last.

3.2 Data Collection

Table 1: Aluminium production at different periods

Time	GDP(k $)	Population(billion)	Power (MWh)	Automobiles(Mu)	Al prod.(Mt)
1980	0.267	0.687322	0.142	NA	0.199
1981	0.271	0.702821	0.153	NA	0.199
1982	0.275	0.718426	0.159	NA	0.229
1983	0.293	0.734072	0.168	NA	0.245
1984	0.28	0.749677	0.184	NA	0.251
1985	0.301	0.765147	0.195	NA	0.26
1986	0.315	0.781893	0.21	NA	0.325
1987	0.346	0.79868	0.222	NA	0.344
1988	0.359	0.81559	0.243	NA	0.376

1989	0.352	0.832535	0.26	NA	0.391
1990	0.374	0.849515	0.276	0.507756	0.451
1991	0.309	0.86653	0.295	0.566345	0.458
1992	0.278	0.882821	0.309	0.749908	0.461
1993	0.307	0.899392	0.326	0.96198	0.465
1994	0.353	0.915697	0.347	1.156899	0.474
1995	0.382	0.93218	0.365	1.533455	0.478
1996	0.409	0.948759	0.366	1.788349	0.501
1997	0.426	0.965428	0.382	1.919345	0.523
1998	0.424	0.98212	0.394	2.988105	0.529
1999	0.451	0.999016	0.399	3.566235	0.554
2000	0.453	1.016	0.402	4.033766	0.6096
2001	0.463	1.032	0.403	5.499107	0.624
2002	0.484	1.049	0.417	6.577399	0.671
2003	0.563	1.064	0.435	7.899345	0.799
2004	0.668	1.08	0.457	8.467853	0.861
2005	0.762	1.095	0.476	9.743503	0.942
2006	0.857	1.11	0.516	11.087997	1.105
2007	1.105	1.125	0.552	10.85393	1.153
2008	1.065	1.14	0.566	11.172275	1.237
2009	1.195	1.155	0.5785	14.057064	1.347
2010	1.477	1.171	0.618	17.916035	1.877

Where

NA-Not Available

k$- thousand US Dollar

MWh- Megawatt hour

Mu- million units

Mt- million tonnes

CHAPTER 4

ANALYSIS, FORECASTING AND CONCLUSION

Graph Analysis

Summary report

Report validation

Forecasting

Conclusion

4.1 Graph Analysis

- The aim of the investigation was to project the requirement of Aluminium in next two decades. The parameters in which projections were based were GDP, population, power and automobiles were used. The mutual dependency of each factor had been analysed and reported here.
- **Influence of GDP**: The data related to gross domestic product was analysed with respect to that of production of aluminium (Figure8). An analysis with various statistical approaches produces the best fit for a polynomial relation. It was observed from the above graph that as GDP increases the Aluminium production also increases. The increase is moderate between GDP per capita values \$ 200 to \$ 600 and then it rises exponentially.

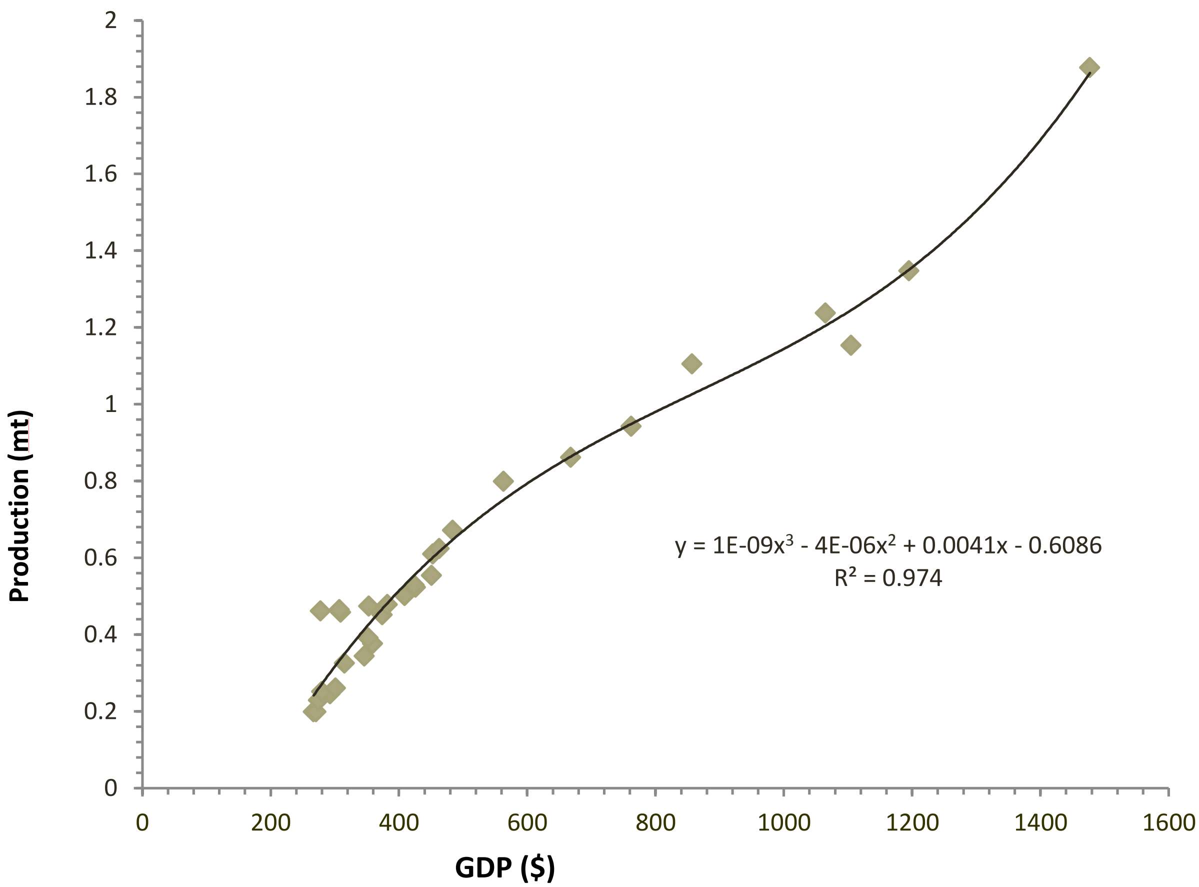


Figure 8: Aluminium production vs GDP

- **Influence of Population**: The data related to population was analysed with respect to that of production of aluminium (Figure9). An analysis with various statistical approaches produces the best fit for a polynomial relation. It was observed from the above graph that as population increases the Aluminium production also increases. From 1980 till 2010 population has been linearly increasing as shown in Figure 9a whereas Aluminium production rose linearly to a period of 22 years and then hyped to an exponential rise with respect to the linear rise in population.

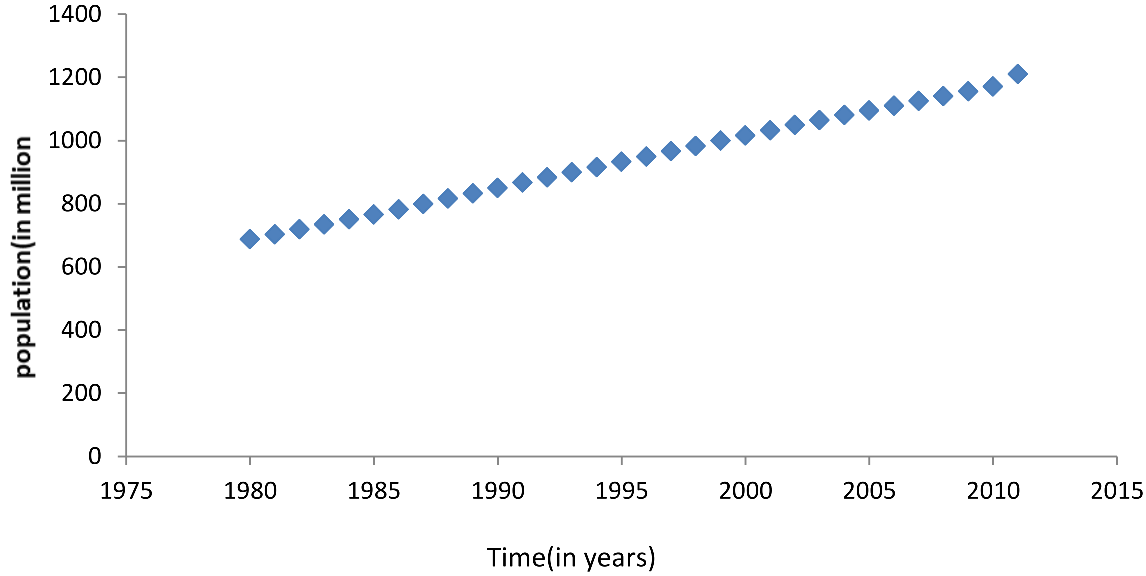


Figure 9a: Population vs time

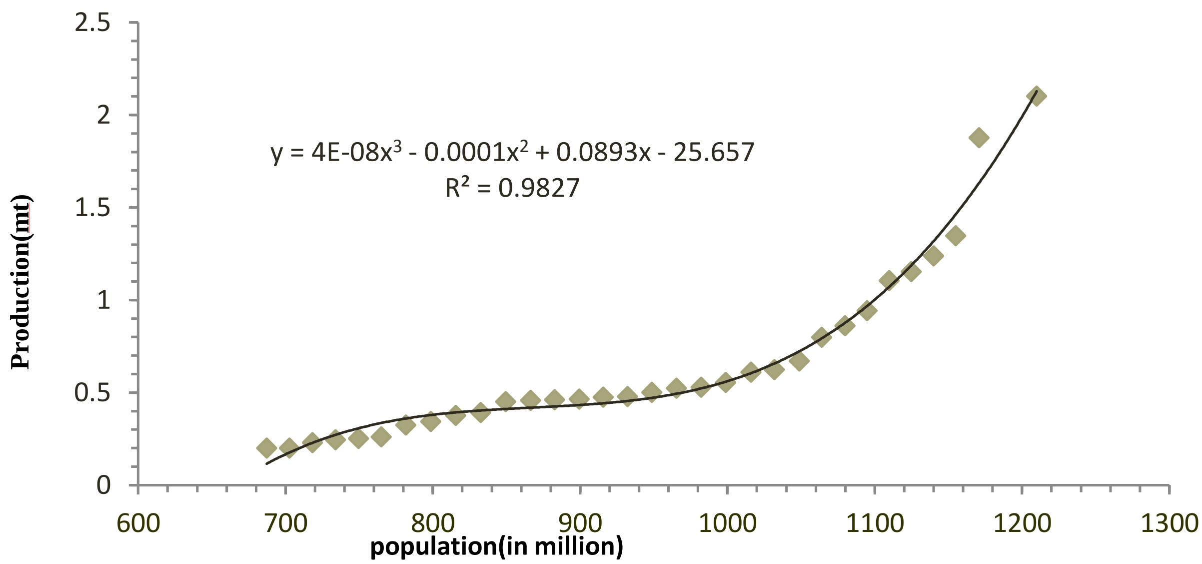


Figure 9b: Aluminium production vs Population

- **Influence of Power**: The data related to Electric power generation was analysed with respect to that of production of aluminium (Figure10). An analysis with various statistical approaches produces the best fit for a polynomial relation. It was observed from the above graph that as electric power generation increases the Aluminium production also increases.

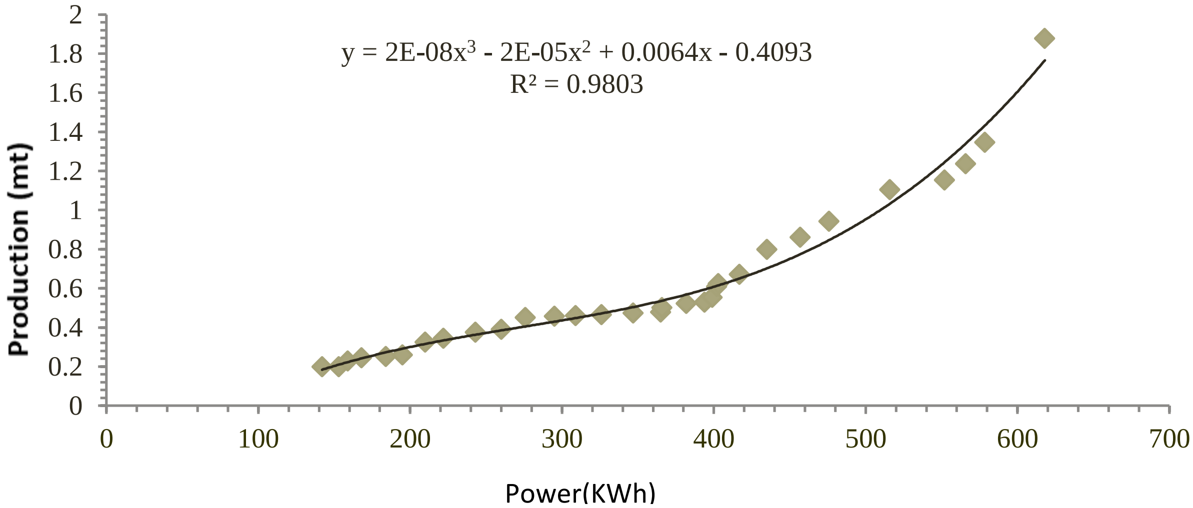


Figure 10: Aluminium production vs Power:

- Influence of Automobiles: The data related to automobiles was analysed with respect to that of production of aluminium (Figure11). An analysis with various statistical approaches produces the best fit for a polynomial relation. It was observed from the above graph that as power increases the Aluminium production also increases

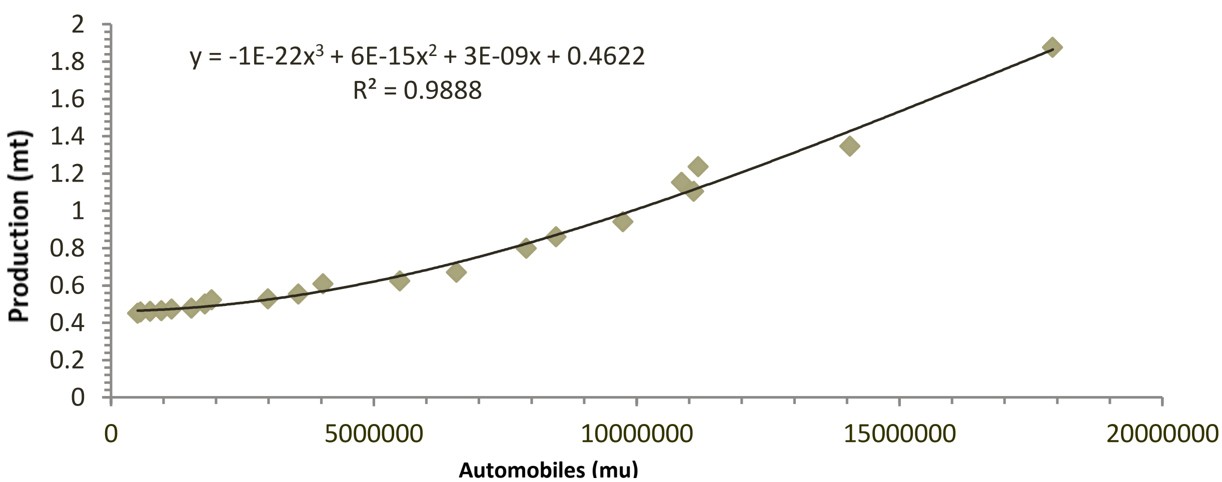


Figure 11: Aluminium production vs Automobiles

- All the above data were combined to obtain comprehensive relation among the parameters. It was observed under Trend Analysis that the factors have a significant role in determining the production of Aluminium.
- Then a multiple regression analysis was done to find a linear relationship in which Aluminium production is a function of Gross Domestic Product, Population, Power and Automobiles.

4.2 Multi-Regression analysis report:

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.992
R Square	0.983
Adjusted R Square	0.981
Standard Error	0.064
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	6.613	1.65330437 8	402.1166	1.24134E-23
Residual	27	0.111	0.00411150 5		
Total	31	6.724			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.463	0.578	2.530	0.018
GDP(thousand $)	0.149	0.238	0.629	**0.535**
Population(billion)	-2.436	0.968	-2.517	0.018
Power(MWh)	3.235	1.133	2.854	0.008
Automobiles(mu)	0.054	0.013	4.090	0.000

The Model Equation includes all the parameters and is presented below:

Al. Production (mt) = 1.463 + 0.15* A - 2.44* B + 3.23*C + 0.05*D

Where

A = GDP (in k$)

B = Population (in billion)

C = Power (in megawatt hour)

D = Automobiles (in million units)

Inference from above summary reports:

- As the p value of GDP is higher, the latter does not have a significant effect in the production dynamics of the Aluminium sector as compared to others. In addition to the overall P value, multiple regression also report an individual P value for each independent variable. A low P value here means that this particular independent variable significantly improves the fit of the model.
- The overall R^2 value is high, and the corresponding P value is low, that means the model fits the data well.
- All the factors except Population have a positive impact on the growth of Aluminium industry.
- The coefficient of relation i.e. R^2 value is 0.981 that means 98.1 % change in the Aluminium production is explained by the change in the Gross Domestic Product, Population, Power and Automobiles.
- Standard error has been found low i.e. 0.064.

4.3 Validation of the reports:

- The reports Aluminium production and factors that is GPA, Population, Power and Automobiles were validated from 2006-2010 using ARIMA (Auto-Regressive Integrated Moving Analysis) model. The reports generated by ARIMA model were almost close to the original reports with minimum error or residuals.
- ARIMA models are, in theory, the most general class of models for forecasting a time series which can be stationarized by transformations such as differencing and logging. In fact, the easiest way to think of ARIMA models is as fine-tuned versions of random-walk and random-trend models: the fine-tuning consists of adding lags of the differenced series and/or lags of the forecast errors to the prediction equation, as needed to remove any last traces of autocorrelation from the forecast errors.
- As the validation reports were quite satisfactory so a 20 year data of the independent factors were predicted henceforth and put in the aforementioned relation.
- Validation Reports are provided in the Appendix

4.4 Forecasting

The Aluminium production for next two decades has been forecasted using the Linear series equation as explained earlier. Similarly other influencing parameters have been predicted.

Table 2: Forecasting table

Al prod.(Mt)	GDP(k $)	Population(billion)	Power(MWh)	Auto(Mu)	Time
2.101	1.498	1.186	0.657	20.479	2011
2.210	1.642	1.203	0.682	22.453	*2012*
2.400	1.874	1.219	0.709	24.473	*2013*
2.584	1.933	1.235	0.741	26.490	*2014*
2.780	2.080	1.252	0.774	28.507	*2015*
2.974	2.280	1.268	0.803	30.523	*2016*
3.151	2.365	1.284	0.832	32.540	*2017*
3.343	2.514	1.301	0.863	34.557	*2018*
3.539	2.692	1.317	0.894	36.573	*2019*
3.720	2.796	1.333	0.924	38.590	*2020*
3.909	2.944	1.350	0.954	40.607	*2021*
4.102	3.109	1.366	0.985	42.623	*2022*
4.288	3.225	1.382	1.015	44.640	*2023*
4.477	3.372	1.399	1.046	46.657	*2024*
4.668	3.529	1.415	1.076	48.673	*2025*
4.854	3.653	1.432	1.106	50.690	*2026*
5.044	3.799	1.448	1.137	52.707	*2027*
5.234	3.950	1.464	1.167	54.723	*2028*
5.421	4.080	1.481	1.197	56.740	*2029*
5.610	4.225	1.497	1.228	58.757	*2030*

4.5 Conclusion

The following conclusions have been derived:

- From the data analysis we can conclude that Aluminium production is highly influenced by the
  - GDP growth of a nation
  - Growth in population
  - Generation of Electric Power
  - Automobile production
- Coefficient of correlation (R^2) is as high as 0.981 which adds testimony to the above statement.
- From the summary reports it can be said that Population has a negative impact on the growth of Aluminium production that means with increase in population Aluminium production decreases.
- From P-values we decipher that
  - GDP growth has an insignificant (statistically) effect towards Aluminium production.
  - Population, power and Automobiles have a significant effect on the growth of Aluminium.
  - Among these Automobile has the most impact towards Aluminium production.
- According to the model, production of Aluminium will increase by 300% by 2030. A production of 5.6 million tonnes of Aluminium will generate a great economy for India and will possibly make India stand in the world arena with distinction.

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Reference:

1. ABARE current issues, 01.3, June, 2001, Climate change and aluminium - impacts ofinternational climate change policy response.
2. Basu N., Chaudhuri B. and Roy P. K.; "Energy management in Indian Aluminum Industries", Energy engineering (Energy eng.) ISSN 0199-8595. 2005, vol. 102, no6, pp. 7-25.
3. European Aluminium Association (EAA) http://www.aluminium.org/

   • Aluminium recycling - the road to high quality products, 2006

   • Collection of aluminium from buildings in Europe - a study by Delft University of Technology, 2006

   • Sustainability of the European aluminium industry, 2006
4. World Bureau for Metal Statistics, 2002
5. Luo Zheng and Soria Antonio, “Prospective Study of the World Aluminium Industry” European Commission, Joint Research Centre, Institute for Prospective Technological Studies 2008.
6. Central Electricity Authority (CEA), 2006. “All India Electricity Statistics, General Review 2006, (Contain data for the year 2004-05)”. Government of India, Ministry of Power, Central Electricity Authority, New Delhi, March 2006.
7. Ministry of Power (MOP), 2007. “Report of for Eleventh Plan (2007-12)” Volume – II” Main Report. The Working Group on Power Working Group on Power for 11th Plan. Government of India. Ministry of Power, New Delhi, February 2007
8. World Bank, 2002. “India's Transport Sector: The Challenges Ahead”, Volume 1: Main Report, May 2002, The World Bank Group.
9. Automotive Mission Plan, 2006-2016. Ministry of Heavy Industries and Public Enterprises, Government of India.
10. BOX, G.E.P. and G.M. JENKINS (1970) Time series analysis: Forecasting and control, San Francisco: Holden-Day.
11. MAKRIDAKIS, S., S.C. WHEELWRIGHT, and R.J. HYNDMAN (1998) Forecasting: methods and applications, New York: JohnWiley & Sons.
12. PANKRATZ, A. (1983) Forecasting with univariate Box–Jenkins models: concepts and cases, New York: JohnWiley & Sons.

13. http://mospi.nic.in/rept%20_%20pubn/ftest.asp?rept_id=siu04_2006&type=NSSO
14. www.commoditywatch.com
15. www.metalworld.co.in
16. www.equitymaster.com
17. www.crnindia.com
18. www.cea.nic.in
19. London Metal Exchange Website
20. International aluminium Institute website.
21. Annual Reports of HINDALCO, NALCO and Vedanta (Sterlite Industries)

Appendix

ARIMA(p,d,q): ARIMA models are the most general class of models for forecasting a time series. They can be stationarized by transformations such as differencing and logging. Now the easiest way to think of ARIMA models is as fine-tuned versions of random-walk and random-trend models: the fine-tuning consists of adding lags of the differenced series and/or lags of the forecast errors to the prediction equation, as needed to remove any last traces of autocorrelation from the forecast errors.

ARIMA stands for "Auto-Regressive Integrated Moving Average." Each ARIMA process has three parts: the autoregressive (or AR) part; the integrated (or I) part; and the moving average (or MA) part. The models are often written in shorthand as ARIMA(p,d,q) where p describes the AR part, d describes the integrated part and q describes the MA part,

AR: This part of the model describes how each observation is a function of the previous p observations. For example, if $p = 1$, then each observation is a function of only one previous observation. That is,

$$Y_t = c + \phi_1 Y_{t-1} + e_t$$

where Y_t represents the observed value at time t, Y_{t-1} represents the previous observed value at time $t-1$, e_t represents some random error and c and ϕ_1 are both constants. Other observed values of the series can be included in the right-hand side of the equation if $p > 1$:

$$Y_t = c + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + e_t.$$

I: This part of the model determines whether the observed values are modelled directly, or whether the *differences* between consecutive observations are modelled instead. If $d = 0$, the observations are modelled directly. If $d = 1$, the differences between consecutive observations are modelled. If $d = 2$, the differences of the differences are modelled. In practice, d is rarely more than 2.

MA: This part of the model describes how each observation is a function of the previous q errors. For example, if $q = 1$, then each observation is a function of only one previous error. That is,

$$Y_t = c + \theta_1 e_{t-1} + e_t.$$

Here e_t represents the random error at time t and e_{t-1} represents the previous random error at time $t-1$. Other errors can be included in the right-hand side of the equation if $q > 1$.

1. Table 3:ARIMA reports for Aluminium production

XLSTAT 2012.2.03 - ARIMA - on 4/15/2012 at 4:18:55 PM
Time series: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$A$2:$D$32 /26 rows and 4 columns
Date data: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$F$2:$F$32 /26 rows and 1 column
Confidence intervals (%): 95
Center: Yes
Model parameters: p = 1 / d = 2 / q = 4 / P = 0 / D = 0 / Q = 0 / s = 0
Optimize: Likelihood (Convergence = 0.00001 / Iterations = 500)
Confidence intervals (%): 95
Seed (random numbers): 123456789

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Series1	26	0	26	0.199	1.877	0.611	0.390

Model parameters:

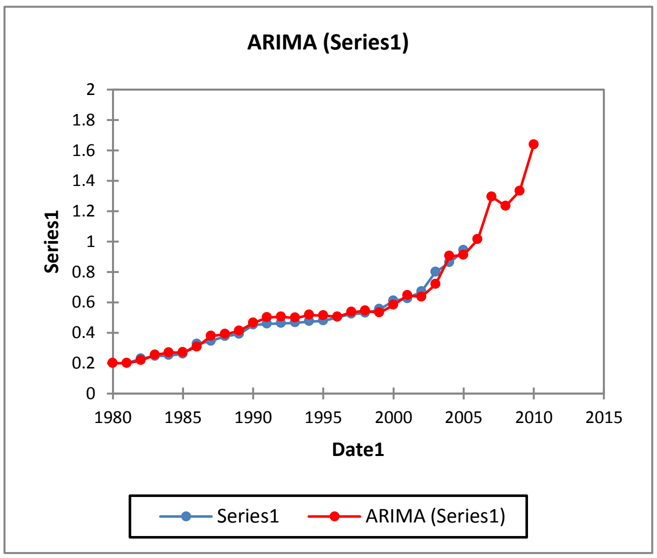
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
Constant	0.009	0.006	-0.002	0.020	0.091	-0.169	0.186

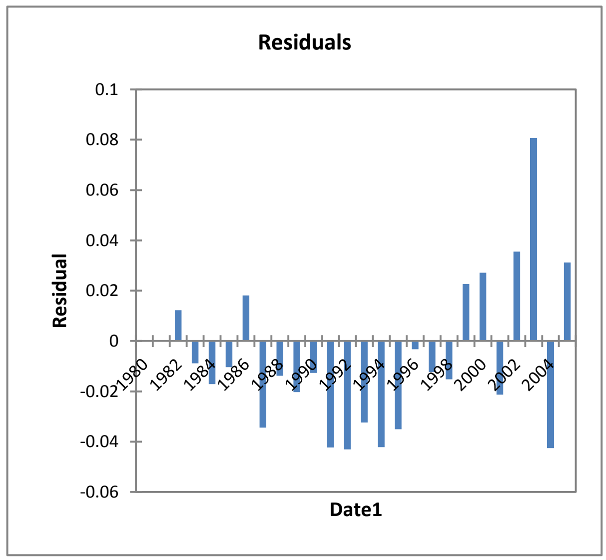
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
AR(1)	-0.104	0.373	-0.835	0.628	0.185	-0.466	0.258
MA(1)	-0.604	0.239	-1.072	-0.137	0.000	-0.604	-0.604
MA(2)	-0.223	0.196	-0.607	0.161	0.000	-0.223	-0.223
MA(3)	-0.604	0.236	-1.068	-0.141	0.000	-0.604	-0.604
MA(4)	1.000	0.250	0.510	1.490	0.000	1.000	1.000

Predictions and residuals:

Observations	Al. prod(mt)	ARIMA(Al. prod(mt))	Residuals	Standardized residuals
1980	0.199	0.199	0.000	0.000
1981	0.199	0.199	0.000	0.000
1982	0.229	0.217	0.012	0.012
1983	0.245	0.254	-0.009	-0.009
1984	0.251	0.268	-0.017	-0.017
1985	0.260	0.270	-0.010	-0.010
1986	0.325	0.307	0.018	0.018
1987	0.344	0.378	-0.034	-0.034
1988	0.376	0.390	-0.014	-0.014
1989	0.391	0.411	-0.020	-0.020
1990	0.451	0.464	-0.013	-0.013

1991	0.458	0.500	-0.042	-0.042
1992	0.461	0.504	-0.043	-0.043
1993	0.465	0.497	-0.032	-0.032
1994	0.474	0.516	-0.042	-0.042
1995	0.478	0.513	-0.035	-0.035
1996	0.501	0.504	-0.003	-0.003
1997	0.523	0.535	-0.012	-0.012
1998	0.529	0.544	-0.015	-0.015
1999	0.554	0.531	0.023	0.023
2000	0.610	0.582	0.027	0.027
2001	0.624	0.645	-0.021	-0.021
2002	0.671	0.635	0.036	0.036
2003	0.799	0.718	0.081	0.081
2004	0.861	0.904	-0.043	-0.043
2005	0.942	0.911	0.031	0.031
2006		1.014		
2007		1.294		
2008		1.234		
2009		1.333		
2010		1.637		





Validation

Time	Actual	Predicted	Difference
2006	1.105	1.013557288	0.091
2007	1.153	1.294446959	0.141
2008	1.237	1.233601193	0.003
2009	1.347	1.332702447	0.014
2010	1.877	1.637250893	0.240

ME	SSE	Variance
0.098067	0.0172129	0.009494727

2. Table 4: ARIMA report for GDP

XLSTAT 2012.2.03 - ARIMA - on 4/6/2012 at 7:55:01 PM
Time series: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$B:$B / 26 rows and 1 column
Date data: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$F:$F / 26 rows and 1 column
Confidence intervals (%): 95
Center: Yes
Model parameters: p = 2 / d = 2 / q = 1 / P = 0 / D = 0 / Q = 0 / s = 0
Optimize: Likelihood (Convergence = 0.00001 / Iterations = 500)
Prediction: 20
Confidence intervals (%): 95
Seed (random numbers): 123456789
Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
GDP(thousand $)	26	0	26	0.267	1.477	0.512	0.313

Results of ARIMA modeling of the GDP(thousand $) series:
Results of search for the best model:

p	q	P	Q	AICC
2	1	0	0	-71.006
2	2	0	0	-67.646
2	3	0	0	-64.453
3	1	0	0	-67.648
3	2	0	0	-65.309
3	3	0	0	-62.318

The best model for the selected selection criterion is displayed in blue
Model parameters:

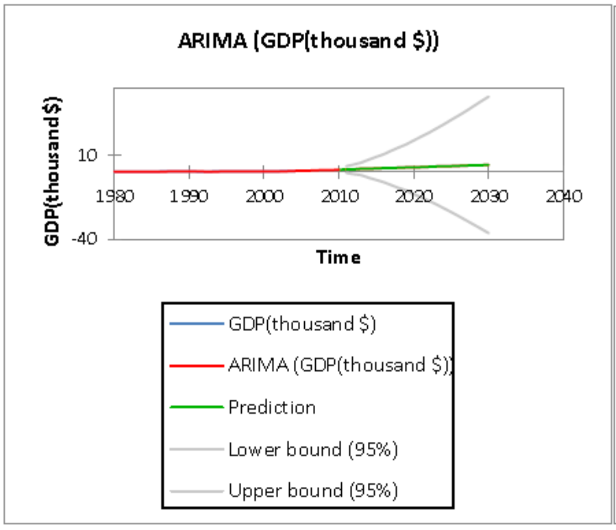
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
Constant	0.005	0.004	-0.003	0.012	0.069	-0.131	0.141

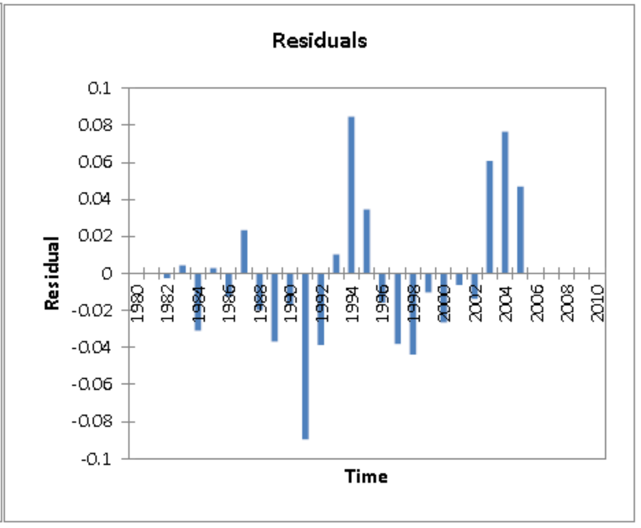
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
AR(1)	-0.900	0.287	-1.463	-0.337	0.157	-1.207	-0.593
AR(2)	-0.761	0.198	-1.149	-0.373	0.132	-1.020	-0.502
MA(1)	-0.040	0.329	-0.685	0.605	0.241	-0.513	0.432

Predictions and residuals:

Observations	GDP(thousand $)	ARIMA(GDP (thousand $))	Residuals	Standardized residuals	Standard error	Lower bound (95%)	Upper bound (95%)
1980	0.267	0.267	0.000	0.000			
1981	0.271	0.271	0.000	0.000			
1982	0.275	0.278	-0.003	-0.003			
1983	0.293	0.289	0.004	0.004			
1984	0.280	0.311	-0.031	-0.031			
1985	0.301	0.298	0.003	0.003			
1986	0.315	0.328	-0.013	-0.013			
1987	0.346	0.323	0.023	0.023			
1988	0.359	0.379	-0.020	-0.020			
1989	0.352	0.389	-0.037	-0.037			
1990	0.374	0.391	-0.017	-0.017			
1991	0.309	0.398	-0.089	-0.089			
1992	0.278	0.317	-0.039	-0.039			
1993	0.307	0.297	0.010	0.010			
1994	0.353	0.268	0.085	0.085			
1995	0.382	0.347	0.035	0.035			
1996	0.409	0.425	-0.016	-0.016			
1997	0.426	0.464	-0.038	-0.038			
1998	0.424	0.468	-0.044	-0.044			
1999	0.451	0.461	-0.010	-0.010			
2000	0.453	0.479	-0.026	-0.026			

2001	0.463	0.469	-0.006	-0.006			
2002	0.484	0.498	-0.014	-0.014			
2003	0.563	0.502	0.061	0.061			
2004	0.668	0.592	0.076	0.076			
2005	0.762	0.715	0.047	0.047			
2006		0.857					
2007		0.972					
2008		1.222					
2009		1.187					
2010		1.403					
2011		1.498			1.000	-0.462	3.458
2012		1.642			1.457	-1.214	4.498
2013		1.874			1.891	-1.833	5.580
2014		1.933			2.744	-3.446	7.311
2015		2.080			3.476	-4.732	8.893
2016		2.280			4.205	-5.962	10.522
2017		2.365			5.169	-7.767	12.497
2018		2.514			6.087	-9.416	14.443
2019		2.692			7.021	-11.069	16.454
2020		2.796			8.103	-13.086	18.677
2021		2.944			9.171	-15.032	20.920
2022		3.109			10.267	-17.015	23.233
2023		3.225			11.463	-19.242	25.692
2024		3.372			12.663	-21.447	28.191
2025		3.529			13.894	-23.704	30.761
2026		3.653			15.198	-26.135	33.441
2027		3.799			16.516	-28.572	36.170
2028		3.950			17.867	-31.068	38.969
2029		4.080			19.273	-33.694	41.855
2030		4.225			20.699	-36.344	44.795





Validation

Time	Actual	Predicted	Difference
2006	0.857	0.856943803	0.000
2007	1.105	0.972169561	0.133
2008	1.065	1.221924997	0.157
2009	1.195	1.186783453	0.008
2010	1.477	1.403482265	0.074

ME	SSE	Variance
0.074309183	0.00954835	0.00503312

3. Table 5: ARIMA report for population

XLSTAT 2012.2.03 - ARIMA - on 4/6/2012 at 8:01:16 PM
Time series: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$C:$C / 26 rows and 1 column
Date data: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$F:$F / 26 rows and 1 column
Confidence intervals (%): 95
Center: Yes
Model parameters: p = 2 / d = 2 / q = 2 / P = 0 / D = 0 / Q = 0 / s = 0
Optimize: Likelihood (Convergence = 0.00001 / Iterations = 500)
Prediction: 20
Confidence intervals (%): 95
Seed (random numbers): 123456789
Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Pop(billion)	26	0	26	0.687	1.171	0.931	0.148

Results of ARIMA modeling of the Pop(billion) series:
Results of search for the best model:

p	q	P	Q	AICC
1	2	0	0	-344.321
1	3	0	0	-346.670
2	2	0	0	-346.702
2	3	0	0	-343.822
3	2	0	0	-344.958
3	3	0	0	-340.787

The best model for the selected selection criterion is displayed in blue
Model parameters:

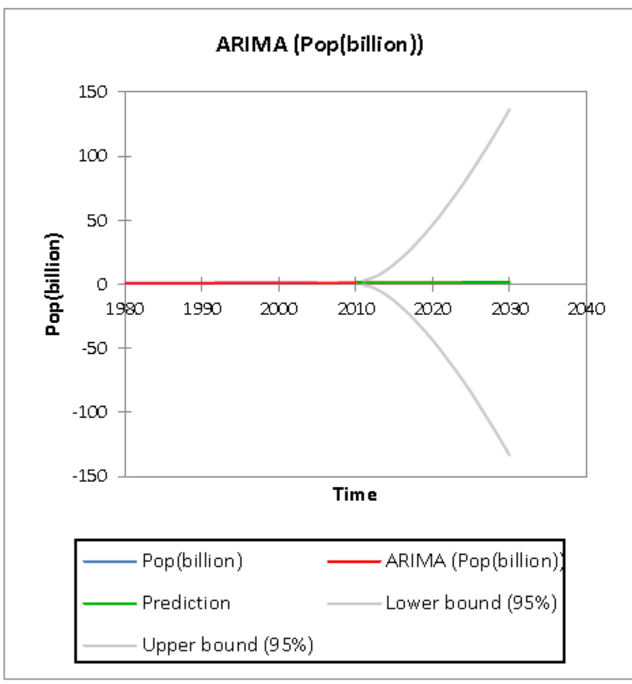
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
Constant	0.000	0.000	0.000	0.000	0.253	-0.496	0.496

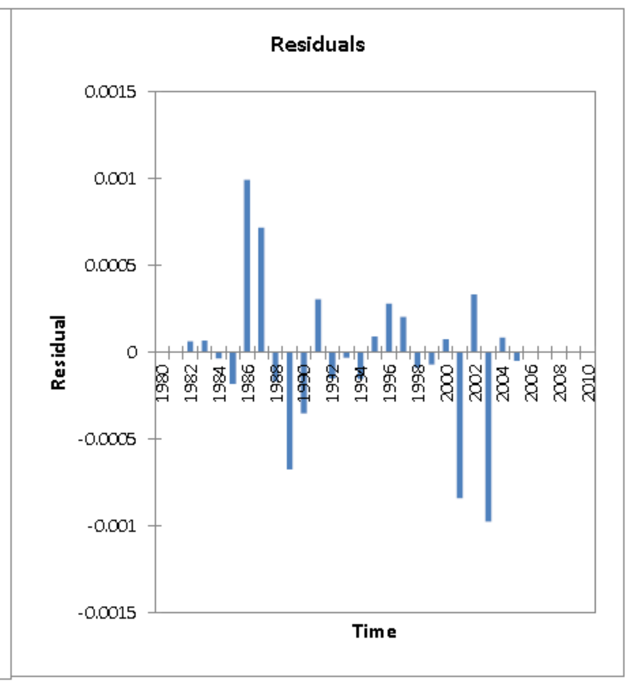
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
AR(1)	0.135	0.213	-0.283	0.552	0.186	-0.229	0.498
MA(1)	-0.837	0.131	-1.093	-0.581	0.000	-0.837	-0.837
MA(2)	1.000	0.208	0.592	1.408	0.000	1.000	1.000

Predictions and residuals:

Observations	Pop(billion)	ARIMA(Pop(billion))	Residuals	Standardized residuals	Standard error	Lower bound (95%)	Upper bound (95%)
1980	0.687	0.687	0.000	0.000			
1981	0.703	0.703	0.000	0.000			
1982	0.718	0.718	0.000	0.000			
1983	0.734	0.734	0.000	0.000			
1984	0.750	0.750	0.000	0.000			
1985	0.765	0.765	0.000	0.000			
1986	0.782	0.781	0.001	0.001			
1987	0.799	0.798	0.001	0.001			
1988	0.816	0.816	0.000	0.000			
1989	0.833	0.833	-0.001	-0.001			
1990	0.850	0.850	0.000	0.000			
1991	0.867	0.866	0.000	0.000			
1992	0.883	0.883	0.000	0.000			
1993	0.899	0.899	0.000	0.000			
1994	0.916	0.916	0.000	0.000			
1995	0.932	0.932	0.000	0.000			
1996	0.949	0.948	0.000	0.000			
1997	0.965	0.965	0.000	0.000			
1998	0.982	0.982	0.000	0.000			
1999	0.999	0.999	0.000	0.000			
2000	1.016	1.016	0.000	0.000			
2001	1.032	1.033	-0.001	-0.001			
2002	1.049	1.049	0.000	0.000			
2003	1.064	1.065	-0.001	-0.001			

2004	1.080	1.080	0.000	0.000			
2005	1.095	1.095	0.000	0.000			
2006		1.110					
2007		1.125					
2008		1.140					
2009		1.155					
2010		1.170					
2011		1.186			1.000	-0.774	3.146
2012		1.203			1.638	-2.008	4.413
2013		1.219			3.026	-4.712	7.150
2014		1.235			4.927	-8.422	10.892
2015		1.252			7.227	-12.914	15.417
2016		1.268			9.854	-18.045	20.581
2017		1.284			12.764	-23.733	26.301
2018		1.301			15.928	-29.919	32.520
2019		1.317			19.326	-36.562	39.196
2020		1.333			22.941	-43.631	46.297
2021		1.350			26.760	-51.100	53.799
2022		1.366			30.773	-58.947	61.680
2023		1.382			34.969	-67.156	69.921
2024		1.399			39.342	-75.710	78.508
2025		1.415			43.884	-84.596	87.426
2026		1.432			48.589	-93.801	96.664
2027		1.448			53.451	-103.315	106.211
2028		1.464			58.466	-113.128	116.056
2029		1.481			63.629	-123.231	126.192
2030		1.497			68.936	-133.616	136.610





Validation

Time	Actual	Predicted	Difference
2006	1.110	1.110031384	0.000
2007	1.125	1.124943158	0.000
2008	1.140	1.139927708	0.000
2009	1.155	1.154997459	0.000
2010	1.171	1.170100285	0.001

ME	SSE	Variance
0.000200001	1.63787E-07	1.54733E-07

4. Table 6: ARIMA reports for Power

XLSTAT 2012.2.03 - ARIMA - on 4/6/2012 at 7:44:36 PM
Time series: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$D:$D / 26 rows and 1 column
Date data: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$F:$F / 26 rows and 1 column
Confidence intervals (%): 95
Center: Yes
Model parameters: p = 2 / d = 2 / q = 2 / P = 0 / D = 0 / Q = 0 / s = 0
Optimize: Likelihood (Convergence = 0.00001 / Iterations = 500)
Prediction: 20
Confidence intervals (%): 95
Seed (random numbers): 123456789
Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Pow(Mwh)	26	0	26	0.142	0.618	0.349	0.136

Results of ARIMA modeling of the Pow(Mwh) series:
Results of search for the best model:

p	q	P	Q	AICC
2	2	0	0	-183.552
2	3	0	0	-180.291
3	2	0	0	-176.084
3	3	0	0	-176.832

The best model for the selected selection criterion is displayed in blue
Model parameters:

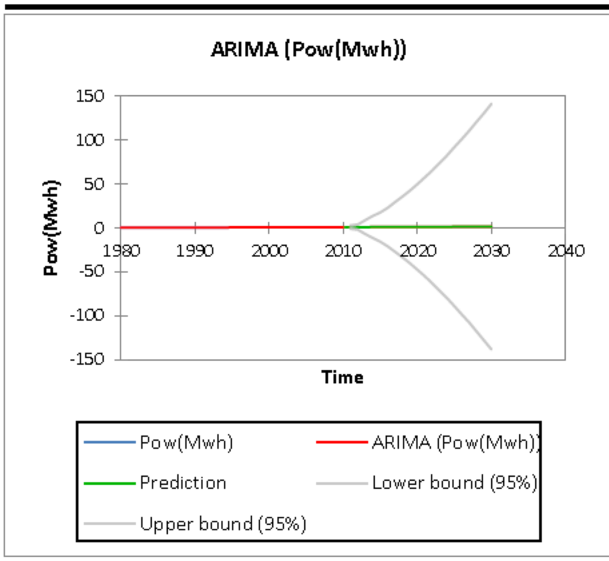
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
Constant	0.001	0.001	-0.001	0.002	0.272	-0.532	0.534

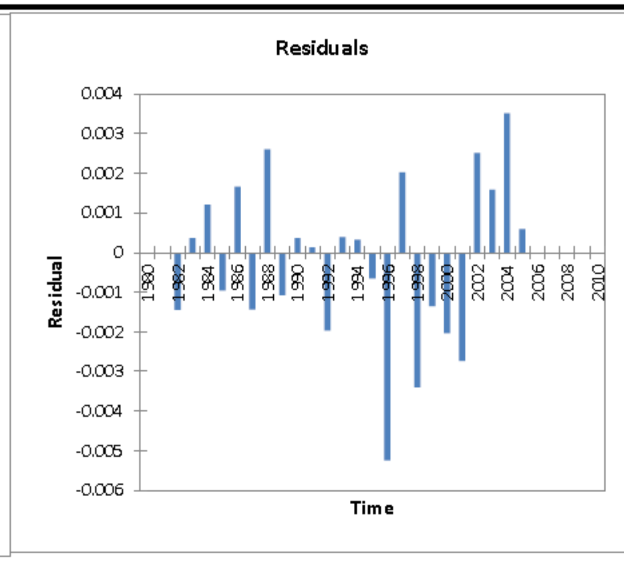
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
AR(1)	-0.019	0.324	-0.654	0.616			
AR(2)	-0.502	0.209	-0.912	-0.091			
MA(1)	-3.231	4.434	-11.922	5.460			
MA(2)	0.095	1.490	-2.826	3.015			

Predictions and residuals:

Observations	Pow(Mwh)	ARIMA(Pow(Mwh))	Residuals	Standardized residuals	Standard error	Lower bound (95%)	Upper bound (95%)
1980	0.142	0.142	0.000	0.000			
1981	0.153	0.153	0.000	0.000			
1982	0.159	0.160	-0.001	-0.001			
1983	0.168	0.168	0.000	0.000			
1984	0.184	0.183	0.001	0.001			
1985	0.195	0.196	-0.001	-0.001			
1986	0.210	0.208	0.002	0.002			
1987	0.222	0.223	-0.001	-0.001			
1988	0.243	0.240	0.003	0.003			
1989	0.260	0.261	-0.001	-0.001			
1990	0.276	0.276	0.000	0.000			
1991	0.295	0.295	0.000	0.000			
1992	0.309	0.311	-0.002	-0.002			
1993	0.326	0.326	0.000	0.000			
1994	0.347	0.347	0.000	0.000			
1995	0.365	0.366	-0.001	-0.001			
1996	0.366	0.371	-0.005	-0.005			
1997	0.382	0.380	0.002	0.002			
1998	0.394	0.397	-0.003	-0.003			
1999	0.399	0.400	-0.001	-0.001			

2000	0.402	0.404	-0.002	-0.002			
2001	0.403	0.406	-0.003	-0.003			
2002	0.417	0.414	0.003	0.003			
2003	0.435	0.433	0.002	0.002			
2004	0.457	0.453	0.004	0.004			
2005	0.476	0.475	0.001	0.001			
2006		0.509					
2007		0.552					
2008		0.570					
2009		0.581					
2010		0.614					
2011		0.657			1.000	-1.303	2.617
2012		0.682			1.601	-2.455	3.820
2013		0.709			4.165	-7.455	8.872
2014		0.741			6.358	-11.721	13.204
2015		0.774			8.487	-15.860	17.407
2016		0.803			11.169	-21.087	22.693
2017		0.832			14.316	-27.227	28.892
2018		0.863			17.601	-33.633	35.360
2019		0.894			21.025	-40.313	42.102
2020		0.924			24.703	-47.493	49.341
2021		0.954			28.617	-55.133	57.042
2022		0.985			32.697	-63.100	65.070
2023		1.015			36.939	-71.383	73.414
2024		1.046			41.362	-80.022	82.113
2025		1.076			45.957	-88.999	91.151
2026		1.106			50.707	-98.278	100.491
2027		1.137			55.607	-107.852	110.125
2028		1.167			60.659	-117.722	120.056
2029		1.197			65.857	-127.879	130.274
2030		1.228			71.194	-138.310	140.766





Validation

Time	Actual	Predicted	Difference
2006	0.516	0.508976383	0.007
2007	0.552	0.551512365	0.000
2008	0.566	0.569817109	0.004
2009	0.579	0.581347683	0.003
2010	0.618	0.614273129	0.004

ME	SSE	Variance
0.003580583	1.72276E-05	5.50883E-06

5. Table 7: ARIMA reports for Automobiles

XLSTAT 2012.2.03 - ARIMA - on 4/6/2012 at 8:18:54 PM
Time series: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$K:$K / 21 rows and 1 column
Date data: Workbook = datafinal.xlsx / Sheet = Sheet1 / Range = Sheet1!$L:$L / 21 rows and 1 column
Confidence intervals (%): 95
Center: Yes
Model parameters: p = 1 / d = 2 / q = 2 / P = 0 / D = 0 / Q = 0 / s = 0
Optimize: Likelihood (Convergence = 0.00001 / Iterations = 500)
Prediction: 20
Confidence intervals (%): 95
Seed (random numbers): 123456789
Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Auto(million units)	21	0	21	0.508	17.916	5.859	5.081

Results of ARIMA modeling of the Auto(million units) series:
Results of search for the best model:

p	q	P	Q	AICC
1	2	0	0	51.452
1	3	0	0	52.111
2	2	0	0	52.603
2	3	0	0	52.942
3	2	0	0	54.456
3	3	0	0	55.143

The best model for the selected selection criterion is displayed in blue
Model parameters:

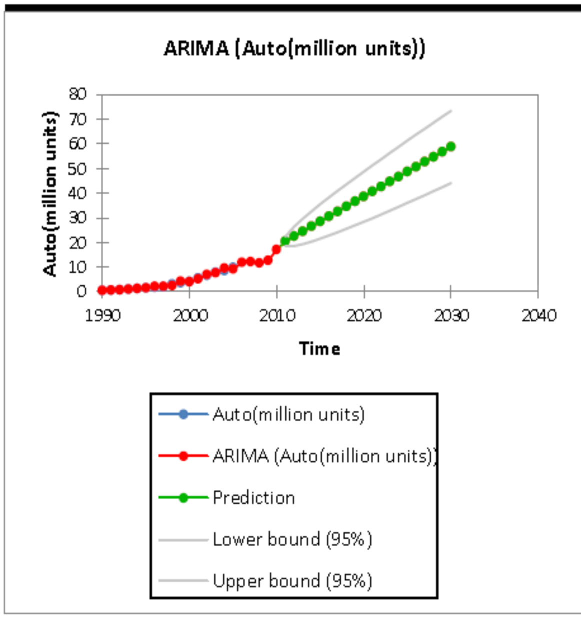
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)
Constant	0.113	0.040	0.035	0.190

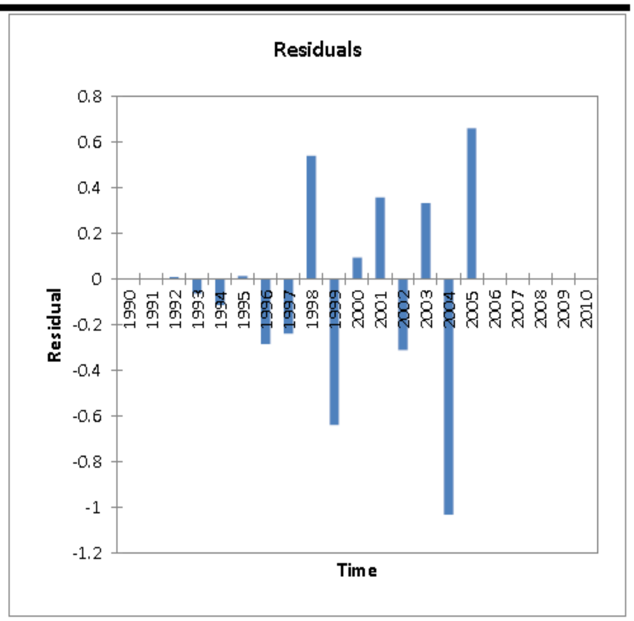
Parameter	Value	Hessian standard error	Lower bound (95%)	Upper bound (95%)	Asympt. standard error	Lower bound (95%)	Upper bound (95%)
AR(1)	-0.078	0.343	-0.750	0.595	0.263	-0.593	0.437
MA(1)	-0.168	0.271	-0.700	0.363	0.146	-0.455	0.118
MA(2)	-0.832	0.258	-1.337	-0.326	0.146	-1.118	-0.545

Predictions and residuals:

Observations	Auto(million units)	ARIMA(Auto(million units))	Residuals	Standardized residuals	Standard error	Lower bound (95%)	Upper bound (95%)
1990	0.508	0.508	0.000	0.000			
1991	0.566	0.566	0.000	0.000			
1992	0.750	0.740	0.009	0.009			
1993	0.962	1.026	-0.064	-0.064			
1994	1.157	1.271	-0.114	-0.114			
1995	1.533	1.520	0.013	0.013			
1996	1.788	2.073	-0.284	-0.284			
1997	1.919	2.158	-0.239	-0.239			
1998	2.988	2.449	0.539	0.539			
1999	3.566	4.206	-0.640	-0.640			
2000	4.034	3.939	0.095	0.095			
2001	5.499	5.141	0.358	0.358			
2002	6.577	6.887	-0.310	-0.310			
2003	7.899	7.567	0.332	0.332			
2004	8.468	9.500	-1.033	-1.033			
2005	9.744	9.083	0.661	0.661			

2006	11.819			
2007	12.064			
2008	11.583			
2009	12.632			
2010	17.045			
2011	20.479	1.000	18.519	22.439
2012	22.453	2.019	18.497	26.410
2013	24.473	2.636	19.306	29.640
2014	26.490	3.137	20.342	32.638
2015	28.507	3.568	21.514	35.499
2016	30.523	3.952	22.778	38.268
2017	32.540	4.302	24.109	40.971
2018	34.557	4.625	25.491	43.622
2019	36.573	4.928	26.915	46.231
2020	38.590	5.212	28.374	48.806
2021	40.607	5.482	29.861	51.352
2022	42.623	5.740	31.373	53.873
2023	44.640	5.986	32.907	56.373
2024	46.657	6.223	34.460	58.853
2025	48.673	6.451	36.030	61.316
2026	50.690	6.671	37.616	63.764
2027	52.707	6.884	39.215	66.199
2028	54.723	7.090	40.826	68.620
2029	56.740	7.291	42.449	71.031
2030	58.757	7.487	44.083	73.430





Validation

Time	Actual	Predicted	Difference
2006	11.088	11.8194111	0.731
2007	10.854	12.06377989	1.210
2008	11.172	11.58265397	0.410
2009	14.057	12.63240719	1.425
2010	17.916	17.04483252	0.871

ME	SSE	Variance
0.92950045	0.991151007	0.1589749